BOULDER DAM

BABCOCK & WILCOX

BOULDER DAM

FOREWORD

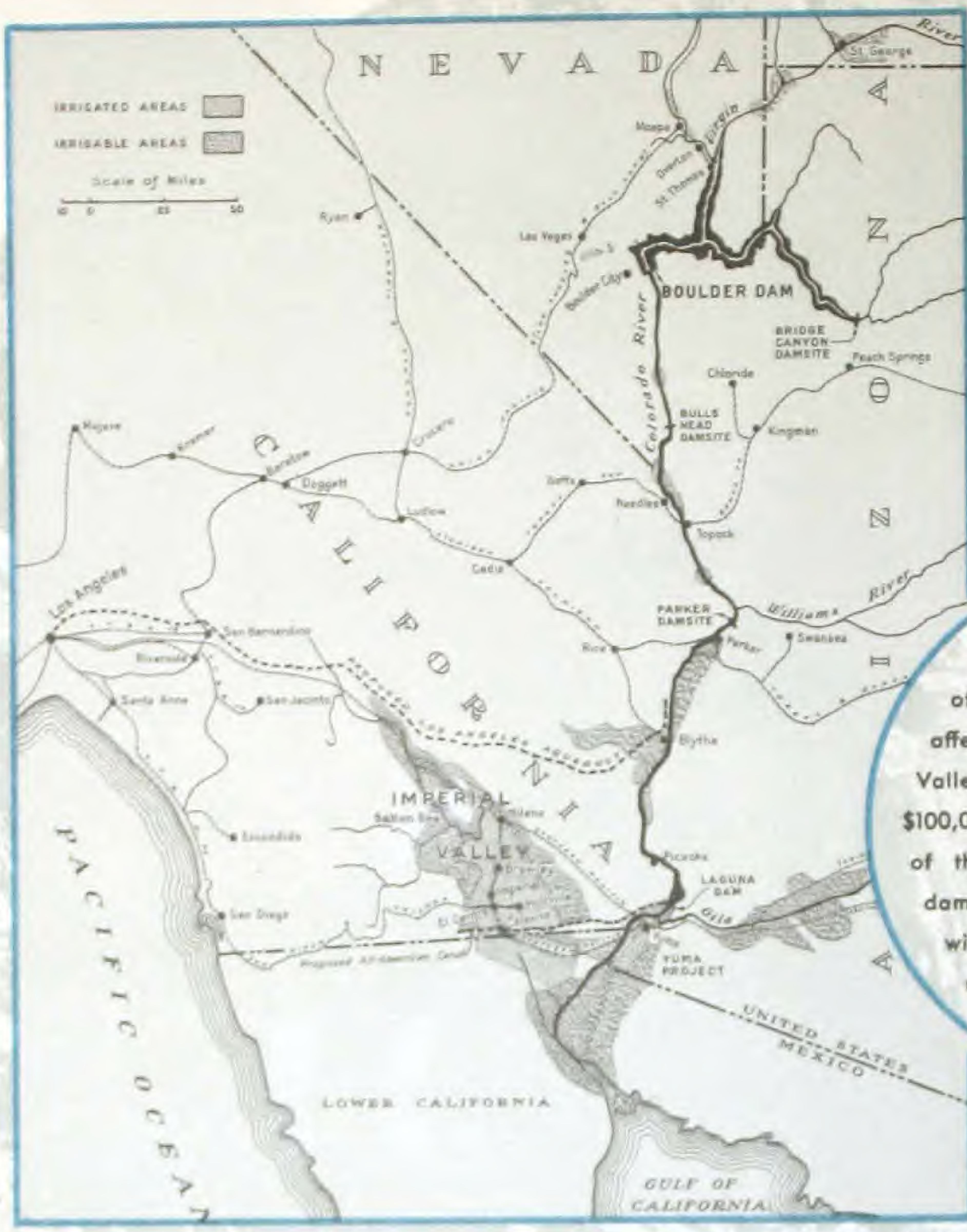
THE Boulder Canyon Project, including Boulder Dam, designed to tame the annual wild rush of the waters of the Colorado River, to provide ultimately for the irrigation of arid but otherwise fertile land, and to generate enough power to make the project self-liquidating, is an undertaking that will mark an epoch in the history of the great engineering achievements of the world.

The Babcock & Wilcox Company is proud of the substantial part it is privileged to take in this stupendous undertaking, and presents in the following pages a brief description of the project as a whole and the more noteworthy features of the fabrication and installation of the fusion-welded plate-steel pipes . . . the largest the world has ever seen . . . to be furnished by the Company for the hydraulic-power and normal-flow-control tunnels of Boulder Dam.

The Company is indebted to the United States Department of The Interior, Bureau of Reclamation, for permission to use most of the data and photographs in this bulletin.

THE BABCOCK & WILCOX COMPANY

BULLETIN S4-A



Location

of Boulder Dam and the territory affected by the project. Imperial Valley now produces crops valued at $100,000,000 annually, and with the flow of the Colorado controlled at the dam, this land of abundant fertility will be freed from the annual menace of the flood stages of that river.

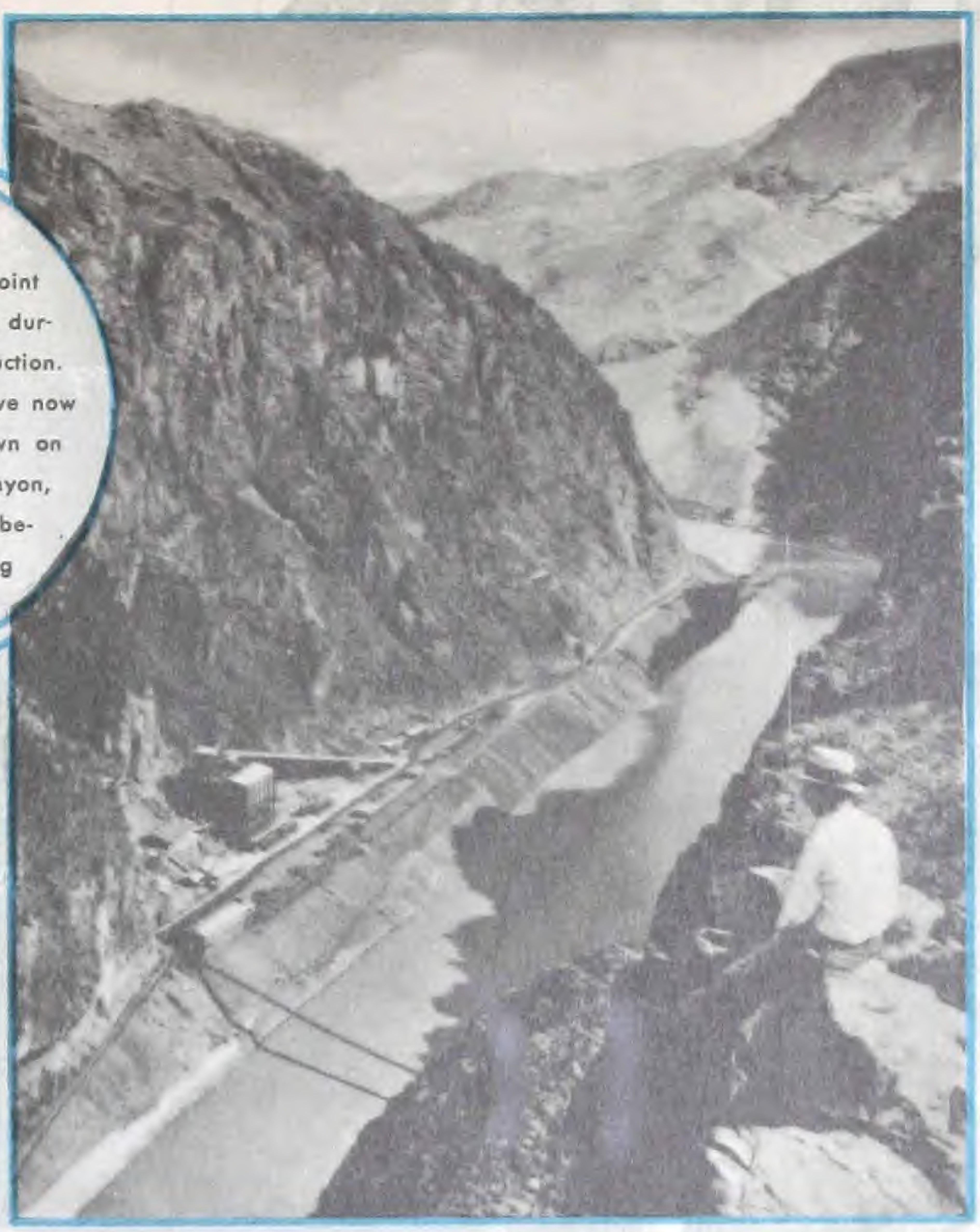
THE COLORADO RIVER

THE waters of the Colorado River originate almost exclusively from the melting snows on the Pacific slope of the Rocky Mountains. Cloudbursts in the summer and heavy rains throughout the river's drainage area make the flow exceedingly erratic, swelling to torrential proportions in the spring. Whereas the minimum flow at Black Canyon is only about 5000 cubic feet per second, the measured maximum flow has reached 210,000 cubic feet per second, and unmeasured floods have reached flows believed to be as high as 300,000 cubic feet per second. Damage costing millions of dollars has been wrought by the Colorado, and millions have been spent to protect Imperial Valley alone from being inundated; but the fury of the Colorado in the flood season presents, in spite of man's best efforts to date, a danger of the gravest sort to the country along its banks and the lowlands around the delta of the river.

The destructive force of these floods is increased enormously by the drop of about 13,000 feet from the head waters in Wyoming and Colorado to the delta at the Gulf of California. This great difference in elevation produces velocities of flow exceeding 10 miles per hour in some parts of the

Black Canyon

looking upstream from a point above the site of Boulder Dam during the early stages of construction. Millions of yards of concrete have now been mixed in the plant shown on the Nevada side of the canyon, the cement and aggregates being delivered to the mixing plant by rail.

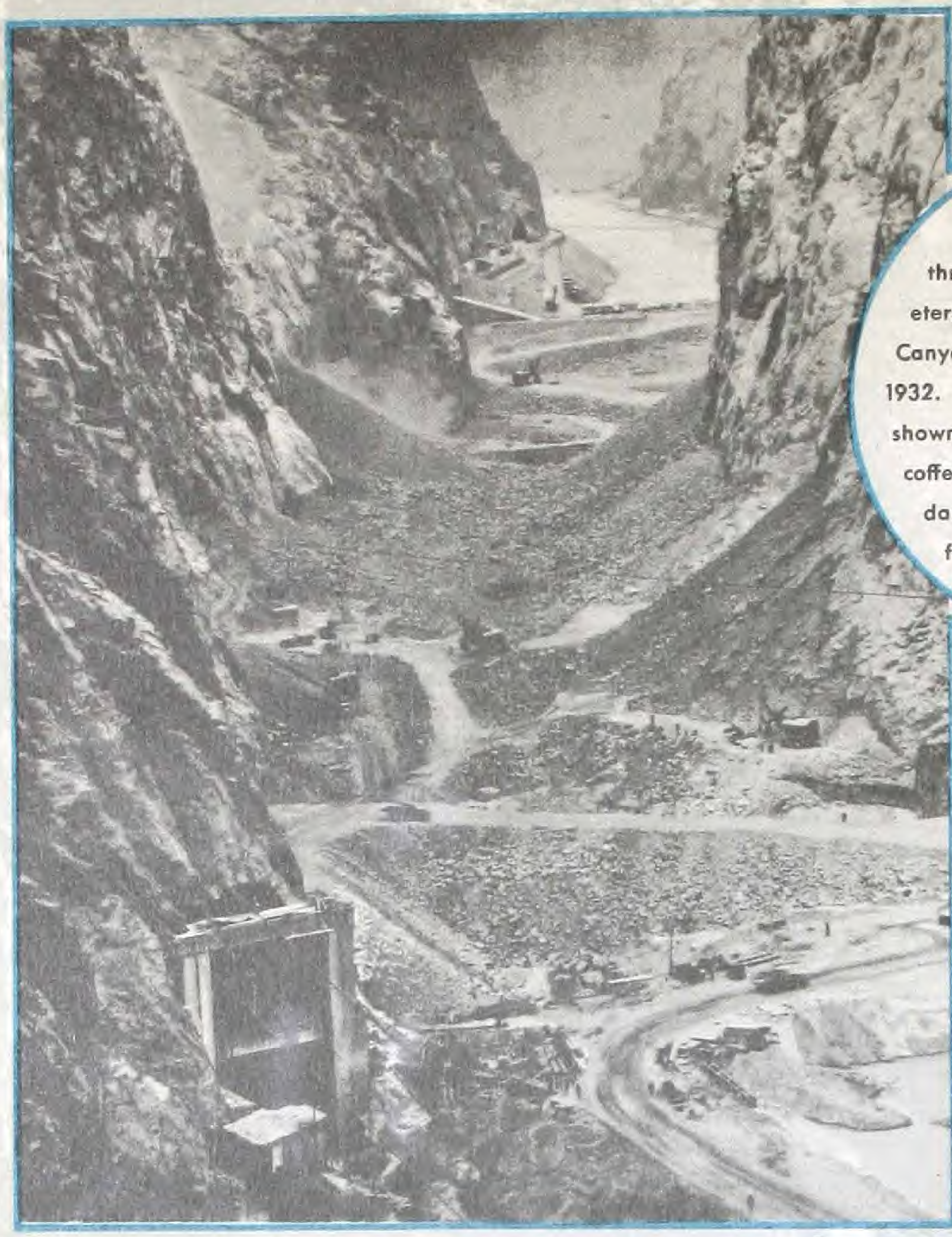


river, with the result that huge quantities of silt are carried down stream by the erosive, turbulent currents. This silt, which is sometimes as much as 15 per cent of the volume of the flow, is washed into the irrigation channels in the agricultural regions adjoining the lower part of the river, and must be dredged out, or the channel banks must be raised, to prevent the water from overflowing the banks as the silt is deposited on the channel beds.

BOULDER CANYON PROJECT

FOR more than fourteen years, the Bureau of Reclamation of the United States Department of the Interior worked on the perfection of a plan whereby the periodic ravages of this temperamental river might be eliminated and its power diverted to useful and profitable ends. Finally, the Bureau developed a plan that is now being carried out under the direction of Dr. Elwood Mead, Commissioner of the Bureau. The plan includes:

1 The construction of a dam, in one of the canyons of the Colorado River, large enough to control the flow of water at all times, to provide flood storage, to store water for irrigation and domestic use, and to serve as a settling basin for mud and silt.



Diverted

through tunnels fifty feet in diameter, the Colorado River left its Black Canyon Channel on November 13, 1932. The temporary rock barriers shown have later been built into huge cofferdams above and below the dam which prevent the river from encroaching on the construction area.

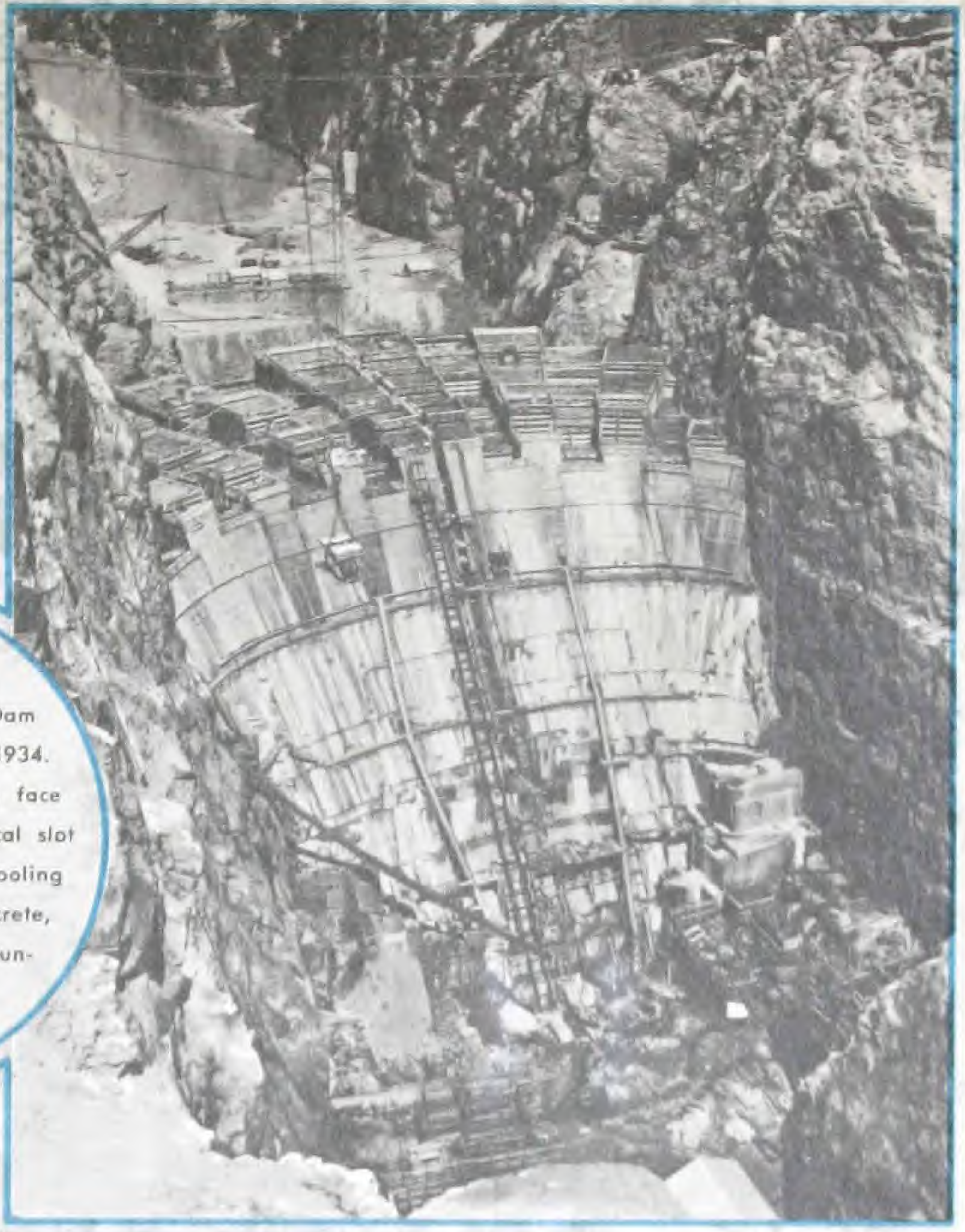
2 The excavation of the All-American Canal, to conduct, for irrigation purposes, water from the Colorado at a point above Yuma, Arizona, to the farm lands in south-eastern California.

3 The construction of a power plant, immediately below the dam, to generate electrical energy, the sale of which would make the entire project self-liquidating.

This plan became known as the Boulder Canyon Project and, as such, was passed by act of Congress and, on December 21, 1928, approved by President Coolidge. As a matter of fact, the final choice of the site for the dam was not at Boulder Canyon but at Black Canyon, about 20 miles down stream.

The authorized cost of the project is:

Boulder Dam and reservoir	$ 70,600,000
Power development equipment	38,200,000
All-American Canal	38,500,000
Interest during construction period	17,700,000
Total	$165,000,000



Rising

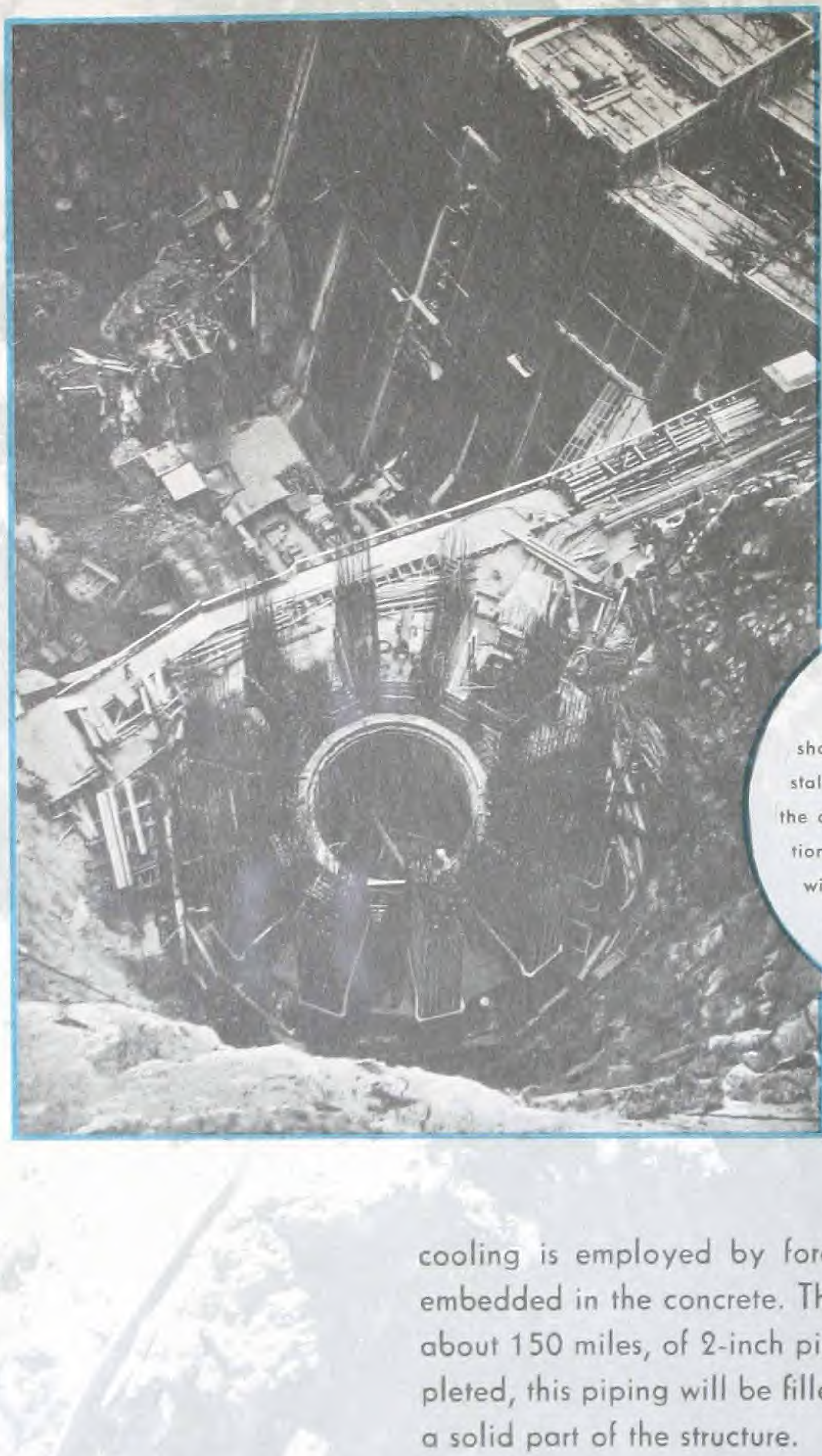
in Black Canyon, Boulder Dam as it appeared late in April, 1934. This view of the downstream face shows the central 8-foot vertical slot for the headers of the water-cooling system embedded in the concrete, as well as part of the foundations of the power plants.

BOULDER DAM AND RESERVOIR

WHEN completed, Boulder Dam will be the highest and largest ever constructed. It is to be of the arch-gravity type, 45 feet thick at the top, 650 feet thick at the base, and will rise about 730 feet above the foundation rock. Its length along the top will be 1180 feet.

The dam proper will contain about 3,400,000 cubic yards of concrete masonry, and 1,000,000 cubic yards more will be used in constructing the power house and related structures. The total quantity of concrete, 4,400,-000 cubic yards, would be sufficient to build a standard paved highway, 16 feet wide, from Miami, Florida, to Seattle, Washington.

The engineering and construction problems that must be solved in building a dam of this size are of a magnitude and complexity that are difficult to realize. For instance, it is estimated that, because of the great mass of the dam, the heat generated by the chemical reaction accompanying the setting of the concrete would not be dissipated for over 100 years under natural conditions. In order to remove this heat quickly, and permit grouting of the construction joints in the dam at low temperature, artificial



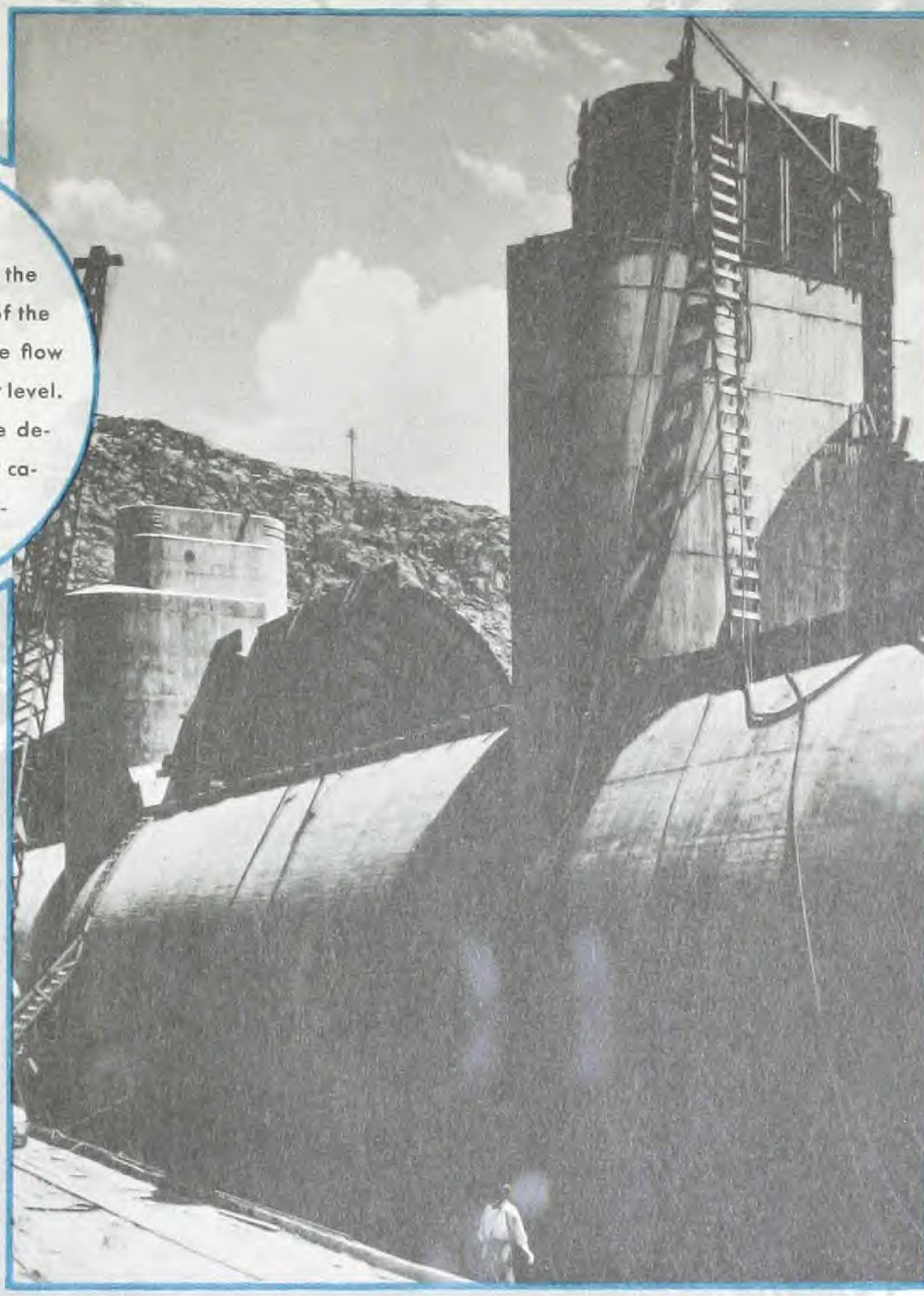
Intake Tower

showing the low-level ring installed. Directly beneath this, and the other three towers, erection-sections of the 30-foot diameter pipe will be installed and will later deliver the stored water to the turbines.

cooling is employed by forcing cold water through a system of pipes embedded in the concrete. This system will require about 800,000 feet, or about 150 miles, of 2-inch pipe. When the cooling process has been completed, this piping will be filled with grout under pressure and thus become a solid part of the structure.

The reservoir created will be the largest artificial lake in the world, measuring 115 miles in length and ranging from a few hundred feet at the dam to 8 miles in width. When filled, it will contain over 30,000,000 acre-feet, or about 10,000,000,000,000 (ten trillion) gallons, of water, enough to cover the state of Connecticut to a depth of ten feet.

Under normal flow conditions it will require over two years to fill the reservoir. The immense storage capacity of the reservoir will make possible an impressive reduction in the volume of water released during flood periods. The flood of 1884, which, it has been estimated, reached a flow at Yuma, Arizona, of 300,000 cubic feet per second, would, with control at Boulder Dam, be reduced to an outflow of but 75,000 cubic feet per second.



Spillway

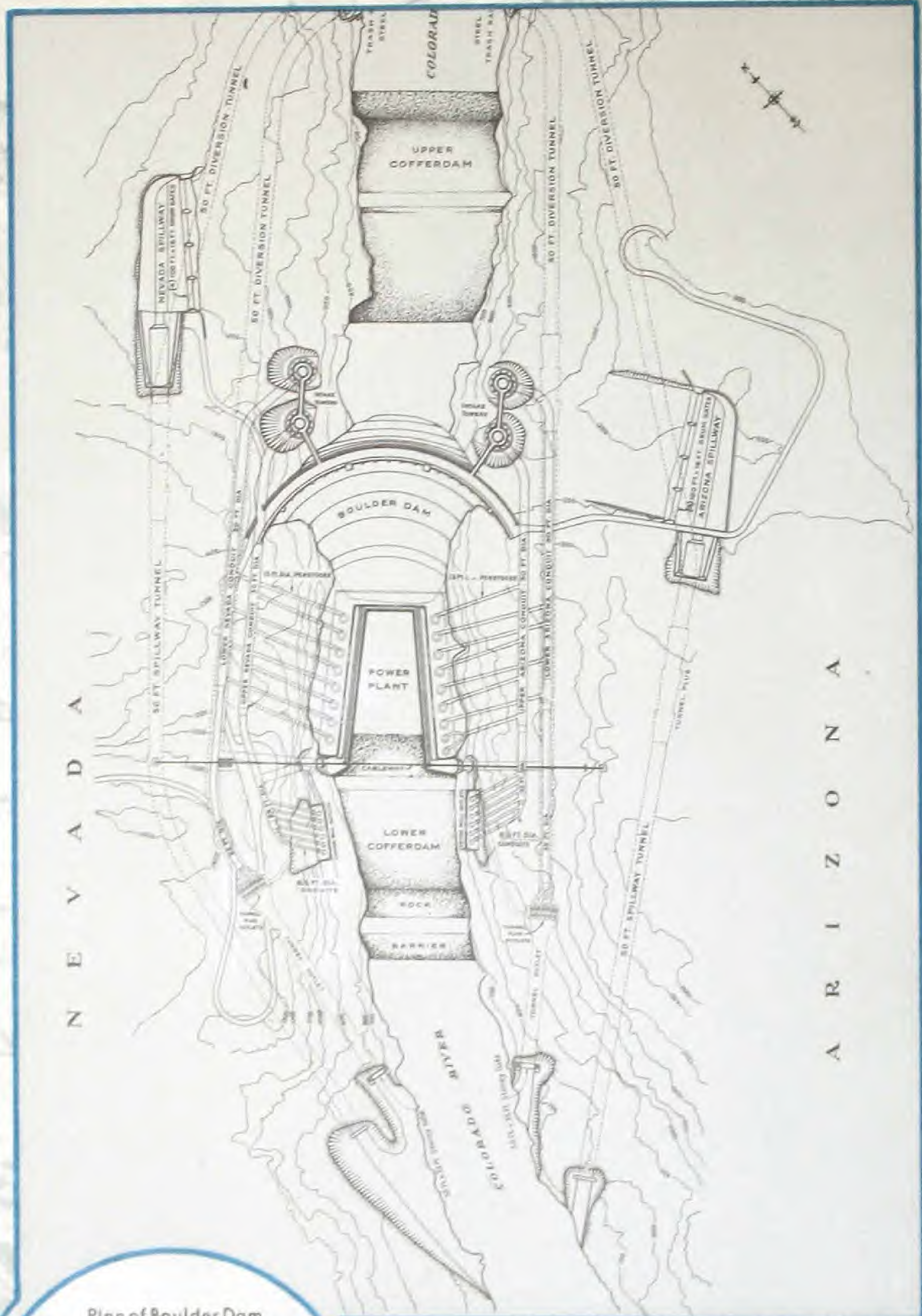
on the Arizona side showing the gate piers and the installation of the drum gates that will control the flow from the reservoir at high water level. These mammoth spillways are designed to provide discharge capacity for 400,000 second-feet of water.

POWER PLANT

THE power plant will be capable of developing 1,835,000 horsepower. For purposes of comparison, it might be stated that the Niagara plant (United States) has a capacity of 557,500 horsepower; Conowingo, 378,000 (ultimate 594,000) horsepower, and Muscle Shoals, 250,000 (ultimate 600,000) horsepower. The continuous firm output of the Boulder Dam power plant will be in excess of 663,000 horsepower.

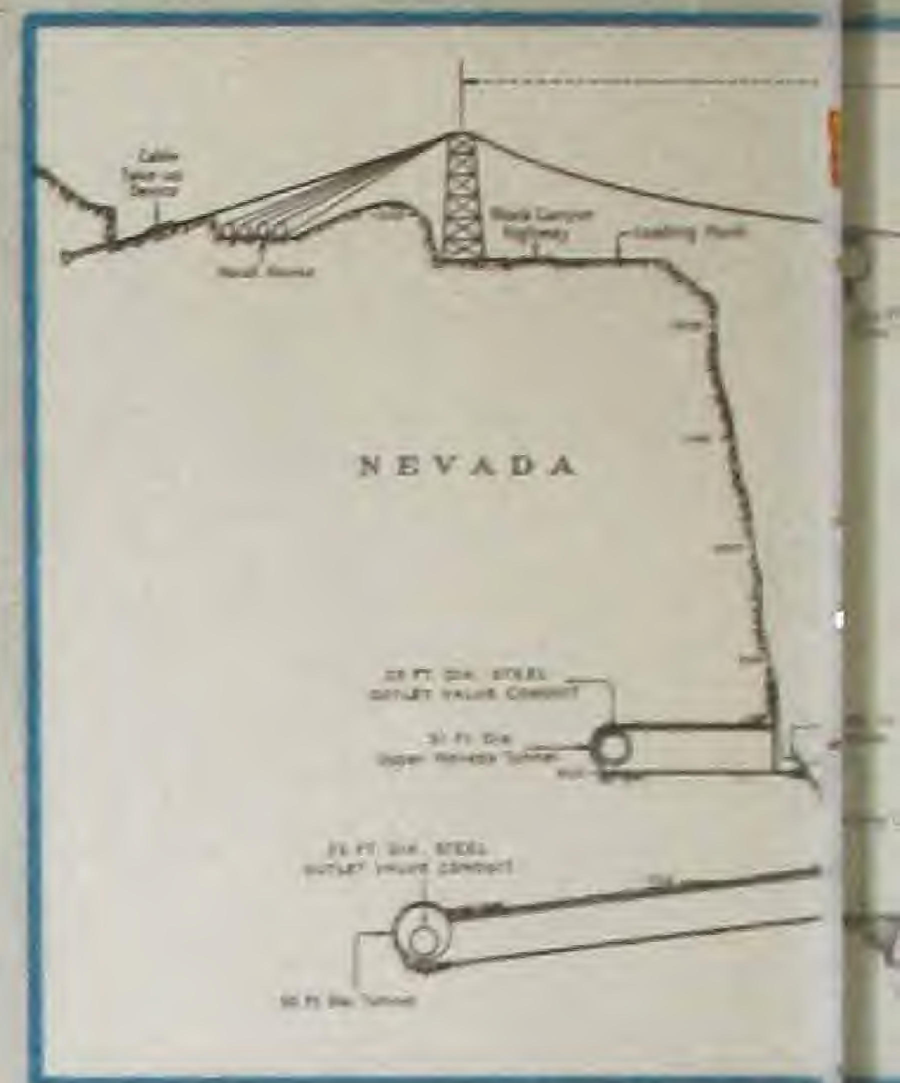
The hydraulic turbines will operate under an average head of 530 feet. The minimum and maximum heads will be 420 and 590 feet, respectively.

The sale of electrical energy will, on the basis of present contracts, pay all operating and maintenance costs and interest charges, and will amortize the investment in 50 years.



Plan of Boulder Dam and appurtenant works, showing the general arrangement of the tunnels and the respective size and final location of the penstock piping now being fabricated by Babcock & Wilcox.

Plan



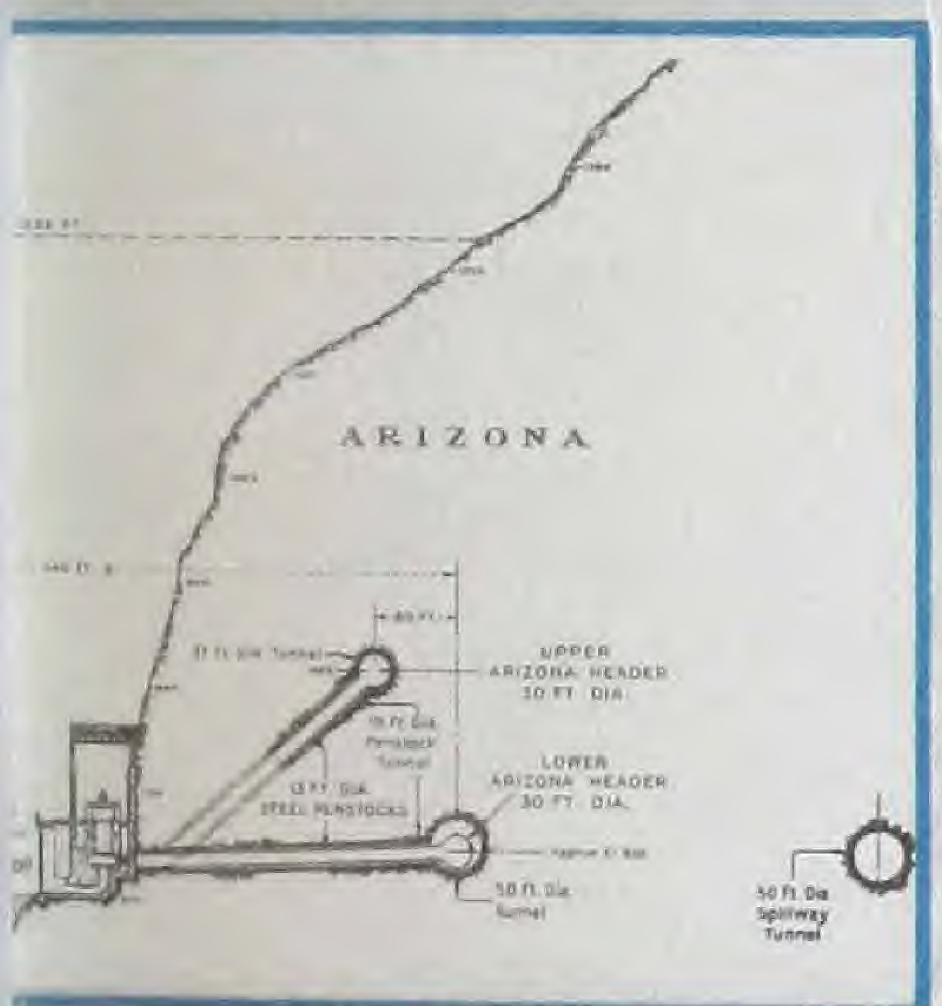
The cross-section sketch above s
ledges, and construction tunnels
transported into the main tunne
eral arrangement of the spillwa

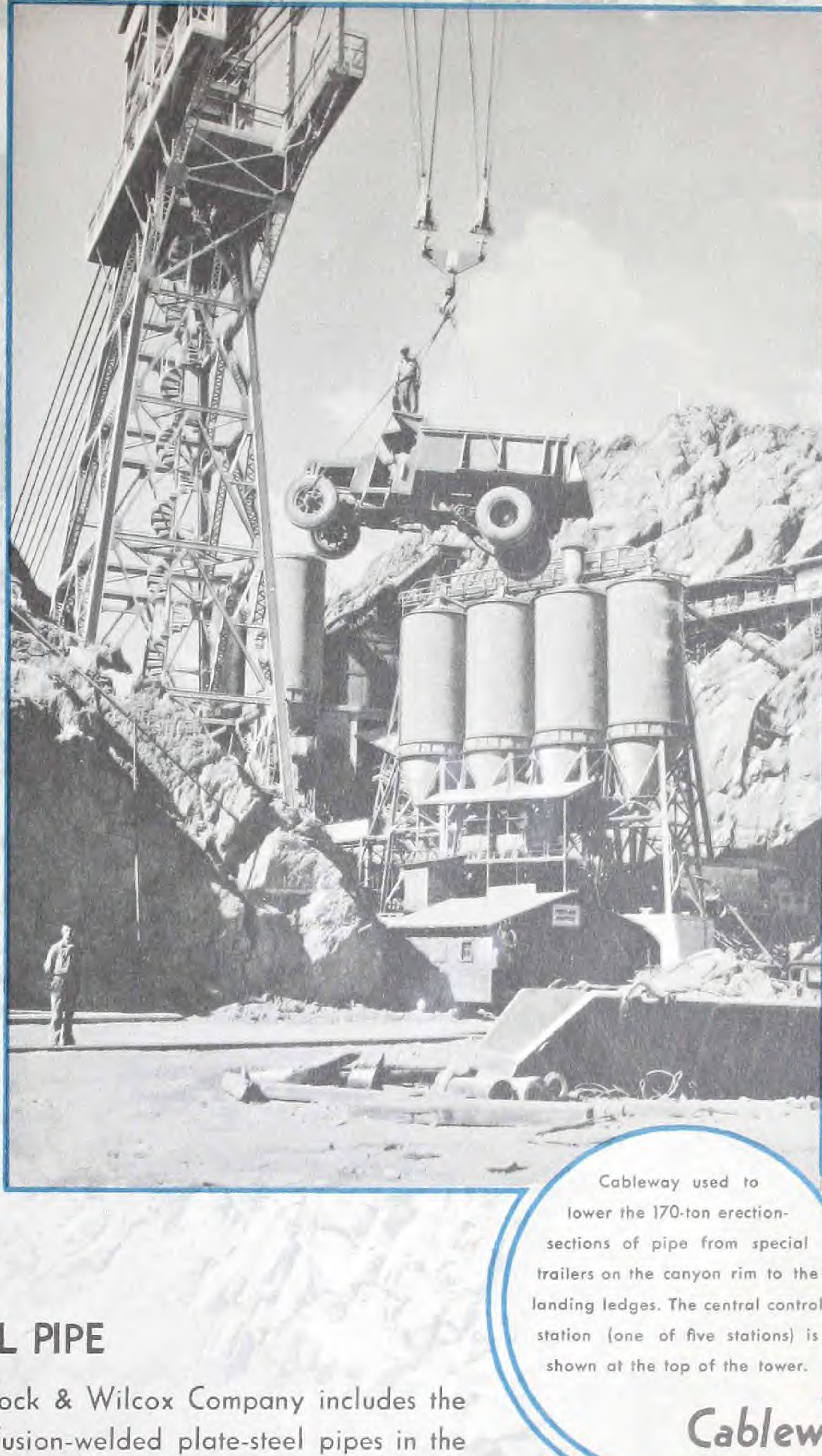
DIVERSION TUNNELS

WHILE the dam is under construction, the river is being diverted through four 50-foot diameter, concrete-lined tunnels driven through the canyon walls, two on each side of the river. These four tunnels have a total length of about 16,000 feet, or more than 3 miles.

When their use for diversion is no longer necessary, the two outer tunnels will be used for the discharge from two spillways, and the inner tunnels will accommodate steel pipes leading to the power house and tunnel plug outlet works. Two additional power tunnels, 37 feet in diameter, one on each side of the river have been driven through the rock, as shown.

ıe location of the cableway, landing-
ıh which the penstock sections will be
ɔw . . . a similar sketch shows the gen-
power tunnels as well as the turbines.





Cableway used to lower the 170-ton erection-sections of pipe from special trailers on the canyon rim to the landing ledges. The central control station (one of five stations) is shown at the top of the tower.

Cableway

STEEL PIPE

THE contract awarded The Babcock & Wilcox Company includes the fabrication and installation of fusion-welded plate-steel pipes in the hydraulic-power and outlet-works tunnels. This is the second largest contract ever let by the United States Department of the Interior, and involves such features as the construction of pipes larger than any heretofore made, the transportation and handling of pipe sections as heavy as many types of standard-gage railroad locomotives, and the exploration of welded seams by the most powerful X-ray equipment available for commercial use.

Four main conduits will conduct water from intake towers above the

Houses and Dormitories

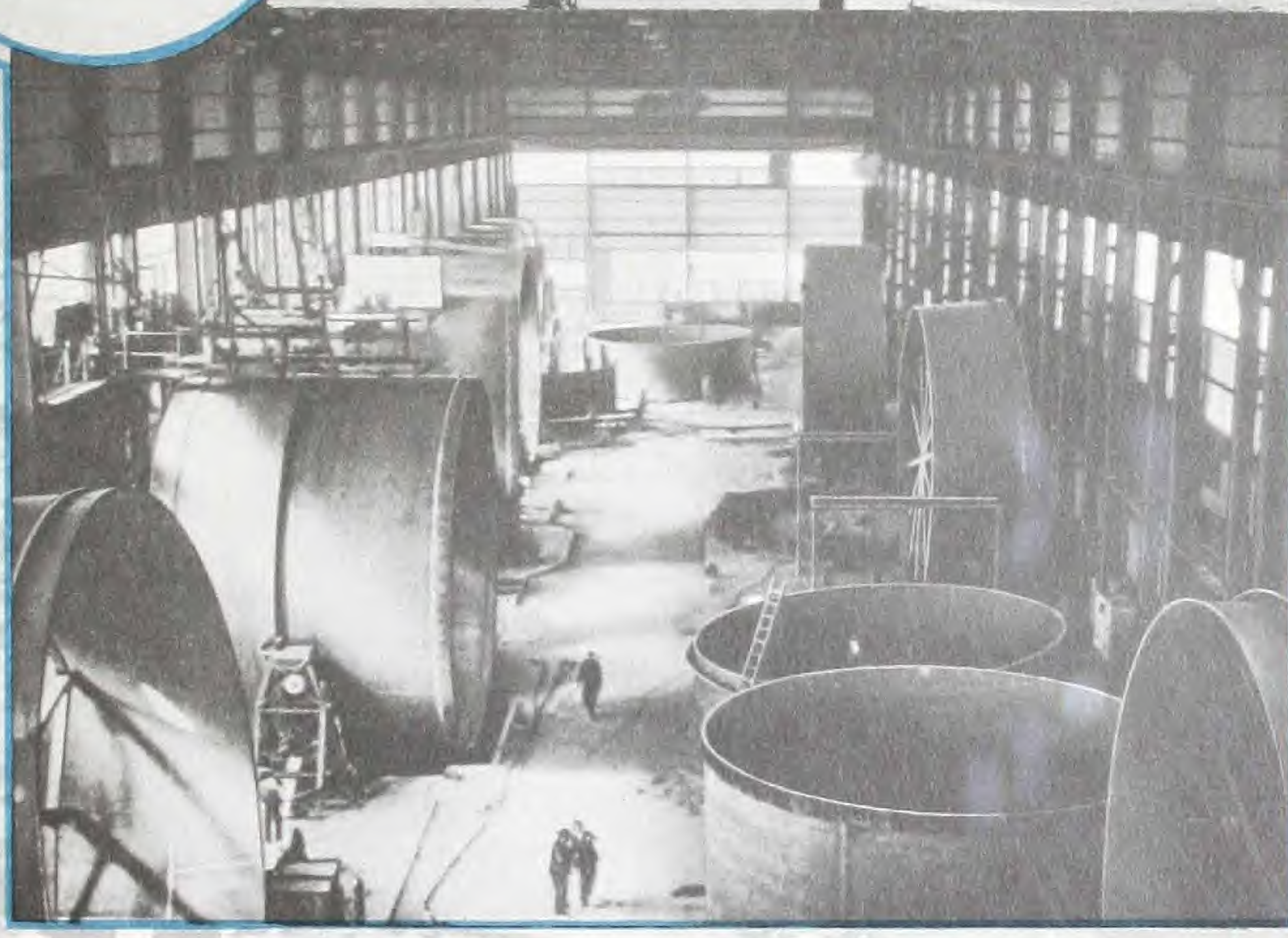
as well as apartments (a total of twenty dwellings) containing every improvement have been built for its employees by The Babcock & Wilcox Company in Boulder City.

dam to the power-house and outlet-works regulating valves below the dam. There will be one upper and one lower conduit on each side of the river. The lower conduits will be located in the 50-foot diversion tunnels nearest the river and at an elevation just above the normal low-water level of the river below the dam. The upper conduits will be installed in 37-foot diameter tunnels running parallel to, and 170 feet above, the lower tunnels.

From each of the main conduits, which are 30 feet in diameter, there will be four 13-foot diameter branches leading to 17 hydraulic turbines in the power house. Below the penstock branches, the main conduits will be reduced to 25 feet in diameter, and from each of these there will be six 8½-foot diameter branches leading to control valves located down stream from the power house. These valves will be used to regulate the flow, to the river below the dam, of surplus water not needed for the power turbines.

Plant and Offices

of The Babcock & Wilcox Company built near the site of the dam. Finished sections may be seen in the yard, while the interior view shows various sizes of pipe under construction.

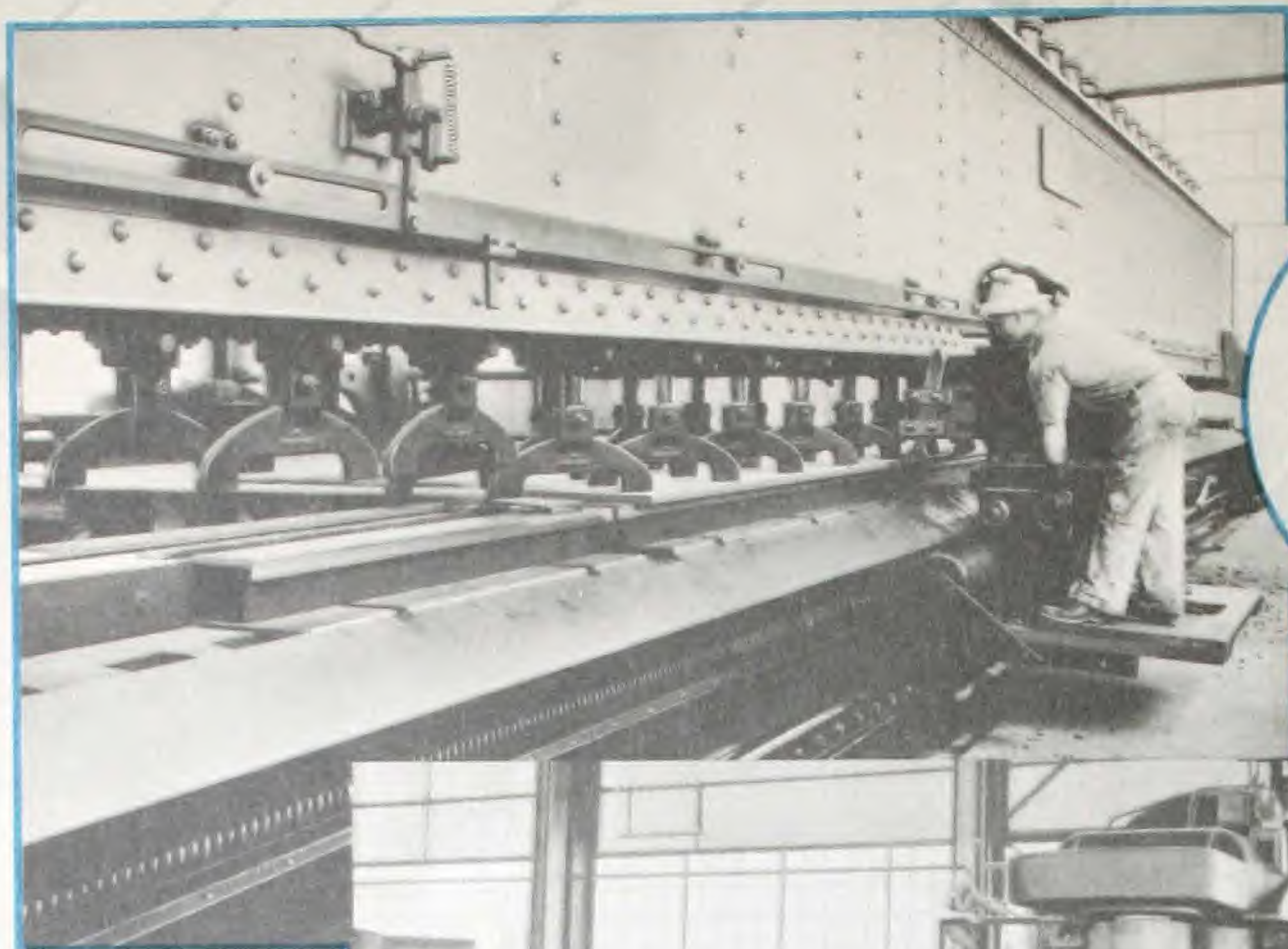


The approximate sizes of the various pipes to be fabricated are:

Length, ft.	Diameter, ft.	Plate Thickness, in.
4700	30	$1\frac{11}{16}$ to $2\frac{3}{4}$
1900	25	$1\frac{5}{8}$ to $2\frac{5}{16}$
5600	13	$\frac{15}{16}$ to $1\frac{5}{16}$
2300	$8\frac{1}{2}$	$\frac{5}{8}$ to 1

Approximately 45,000 tons of steel plate will be used in fabricating this 14,500 feet of pipe.

As the diameters of most of this piping are too great to permit shipment by railroads, it has been necessary to build a fabricating plant on the rocky slopes above the Canyon, about one mile from the site of the dam. The plant equipment includes, among other machinery, a plate-bending roll which, for its width, is heavier and more powerful than any made to date, a



Planer

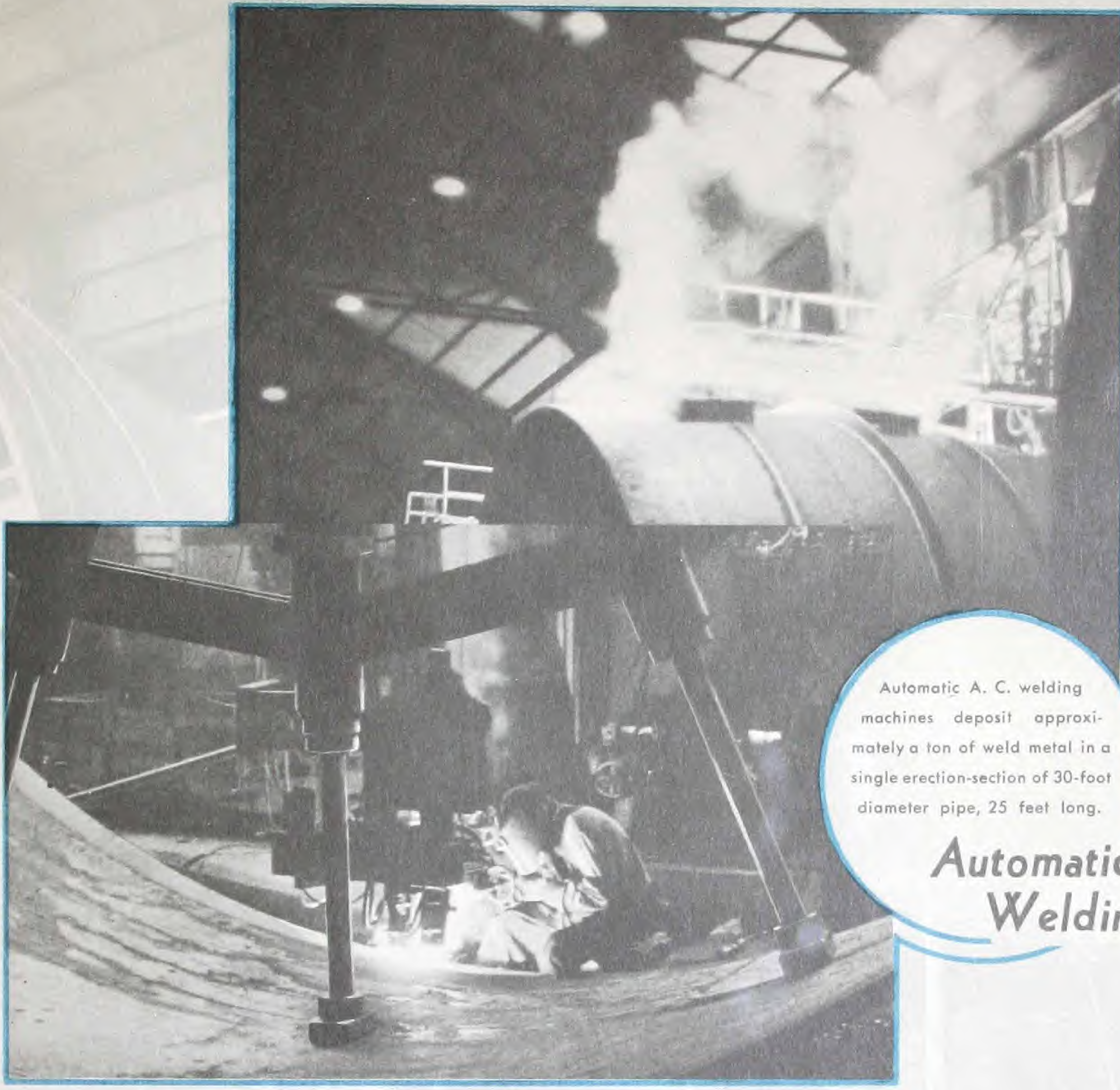
used to machine edges of the plates prior to bending, has a bed 40 feet long and uses pneumatically-operated plungers to hold the plate in place.

Bending Roll

to form plates for the pipe sections, is capable of imposing a load of 3,500,000 pounds on a plate or on a stiffener ring as shown.

stress-relieving furnace of sufficient size to accommodate the 30-foot diameter pipe sections, and a complete laboratory for testing weld specimens.

One piece of 30-foot diameter pipe approximately 12 feet long is made from three steel plates, each about 32 feet long and 12 feet wide, the largest that can be rolled with existing steel-mill equipment. The thickest plates weigh about 23 tons each, and two of these are all that can be shipped in one car from the steel mill to the fabricating plant. These plates, after being formed, are joined by fusion-welding and in accordance with the rules of the A.S.M.E. Boiler Construction Code, Unfired Pressure Vessel Section for Class 1 Welding. In fabricating this pipe, over 400,000 linear feet of welding will be performed. Incidentally, the amount of X-ray film used to prove the soundness of the welds will exceed the total of all that used to date, in this country, for industrial purposes.

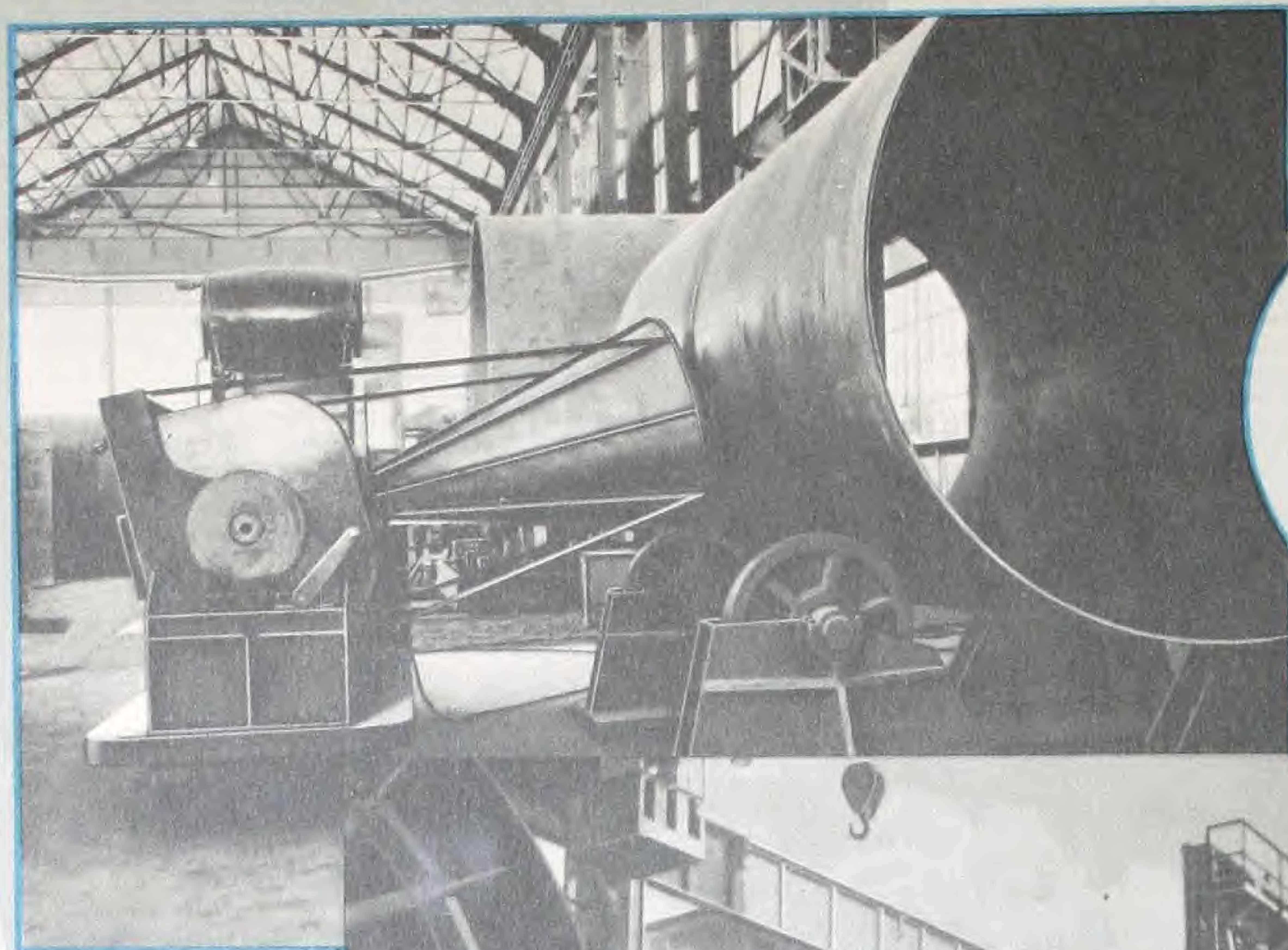


Automatic A. C. welding machines deposit approximately a ton of weld metal in a single erection-section of 30-foot diameter pipe, 25 feet long.

Automatic Welding

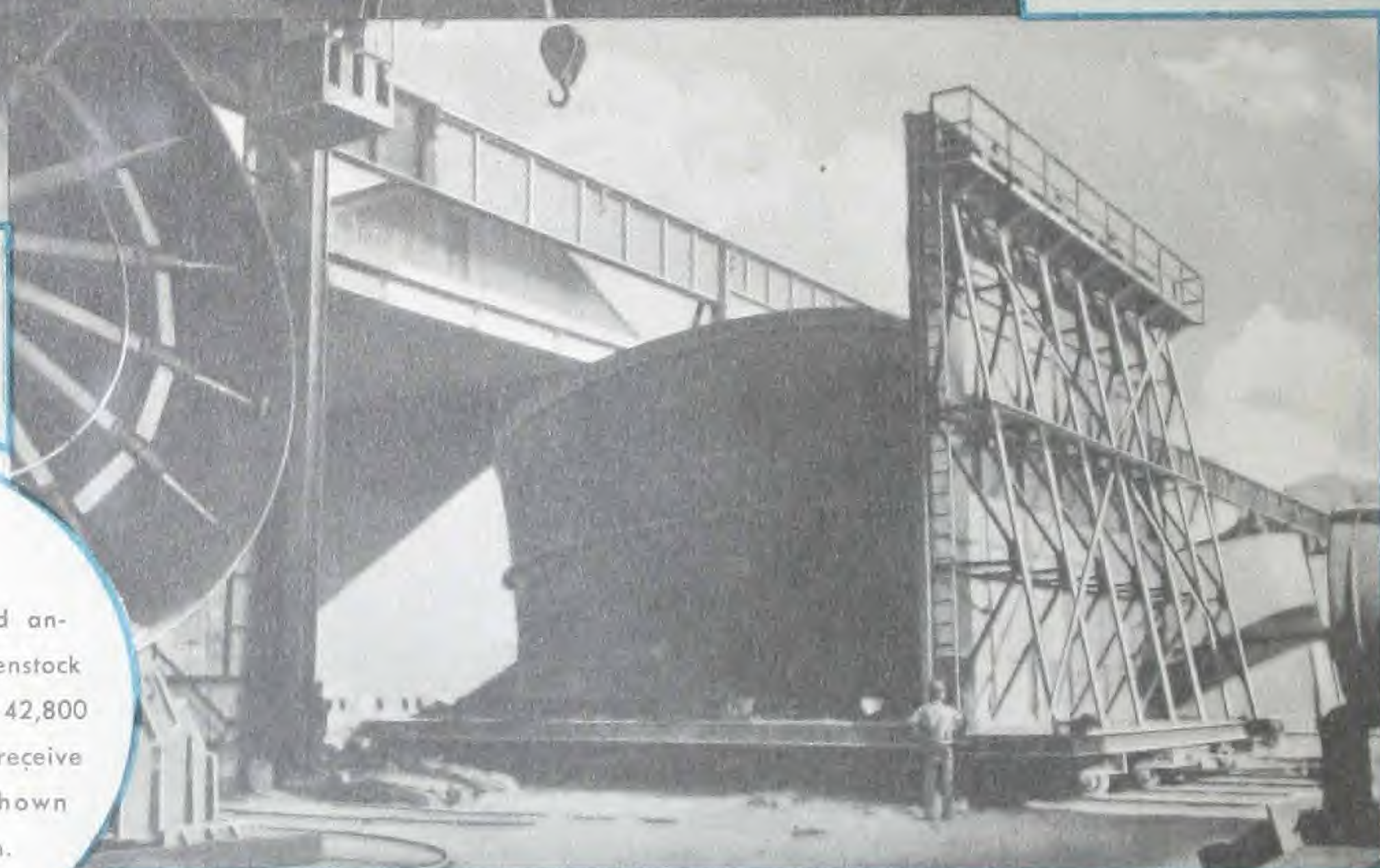
Two pieces of 30-foot diameter pipe, each about 12 feet long, when welded together with a fillet-insert section between them comprise an erection-section which, with support brackets and stiffening rings to hold the pipe in shape, weighs, when made of plate of the maximum thickness required, about 170 tons.

Sections are transported from the fabricating plant to the rim of the canyon on special trailers comparable in load-carrying capacity with those used for mobile coast-defense guns. A cableway extending across the Canyon provides means by which the 170-ton sections may be lowered as much as 600 feet to landing ledges cut into the canyon walls on both sides of the river, at the construction entrances to the four tunnels. This cableway has a clear span of 1256 feet, and its capacity is more than double that of any other used to date for any similar purpose.



X-ray

equipment of 300,000 volt capacity is moved to each section of pipe to explore all welded seams.

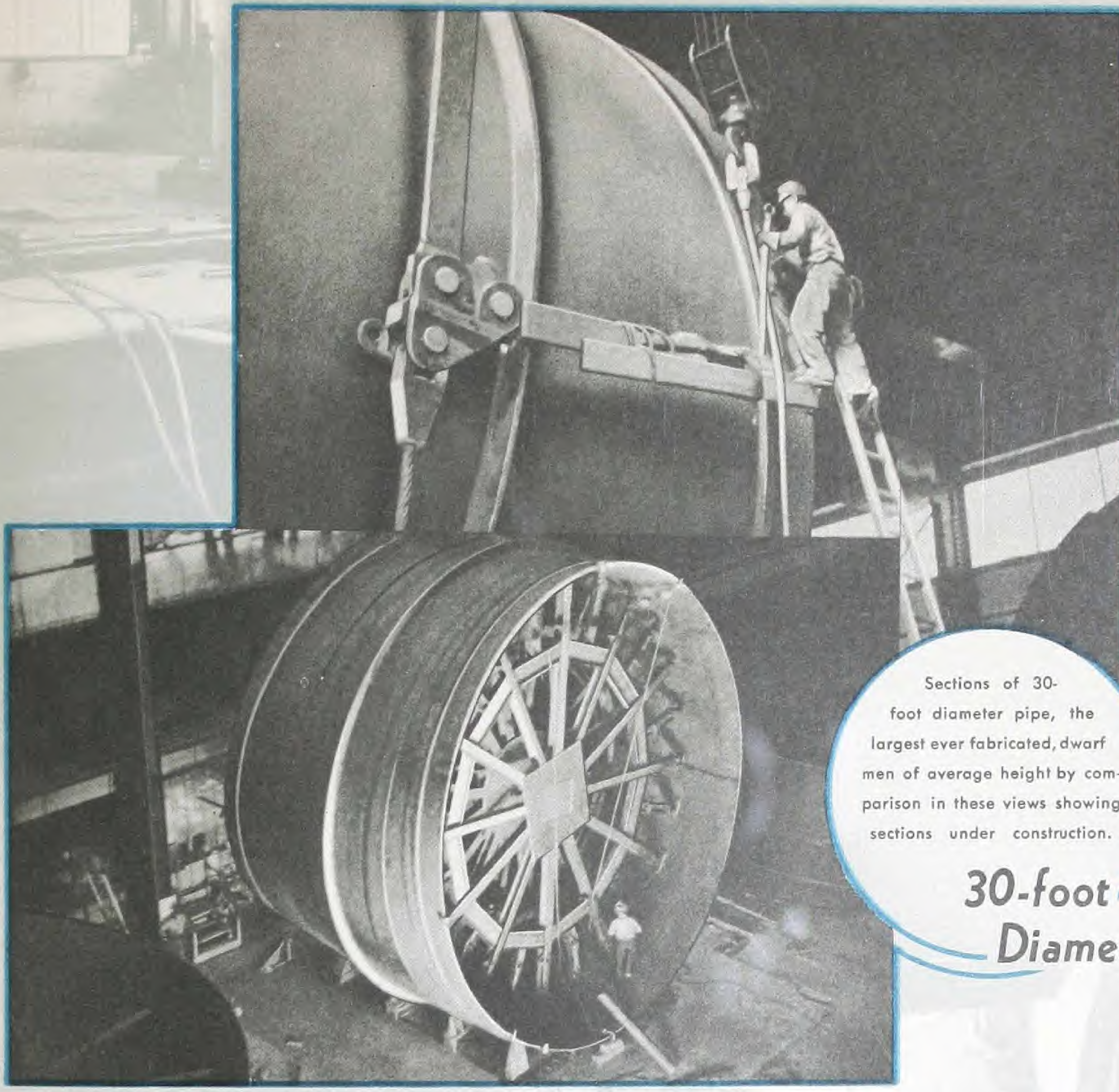


Furnace

for stress-relieving and annealing the finished penstock sections has a volume of 42,800 cu. ft. and will readily receive the 30-foot section shown on the car bottom.

Handling-equipment of special design is used to transport the gigantic pipe sections from the landing ledges into the tunnels and to their final positions, the first sections erected in each tunnel being set vertically under the inlet towers.

In addition to the problems incident to the fabrication, handling, and installation of sections of pipe of a size comparable with that of the average three-story dwelling, the climate itself introduces a problem which is of considerable importance. During the summer, the temperature in this region ranges from 95 degrees fahrenheit at night to as high as 120 degrees during the day. Consequently, the temperatures of the pipes are considerably higher during most of the erection period than they will be when water is turned into them. It is, of course, out of the question to provide expansion joints to absorb the movement due to expansion and contraction either



Sections of 30-foot diameter pipe, the largest ever fabricated, dwarf men of average height by comparison in these views showing sections under construction.

30-foot Diameter

during the erection period or afterwards. Accordingly, the pipes are secured to massive steel-and-concrete anchors, placed about 400 feet apart; and during erection, one circumferential pipe-joint midway between each pair of anchors is left open temporarily, and the final connections made after the pipe has been cooled to the approximate temperature of the water. It may be possible to make these connections during the winter, when the temperature drops to as low as 20 degrees outside the tunnels, and when the air in the tunnels may be sufficiently cold for the purpose, but if this is not feasible, artificial cooling will be employed.

Work on the Boulder Dam Project is so scheduled that generation of electric power by some of the turbines will be considerably in advance of the final completion of the dam. In accordance with this schedule, all pipe work must be completed by March, 1938.

PRODUCTS OF

THE BABCOCK & WILCOX COMPANY

AND SUBSIDIARIES

B & W Water-Tube Boilers
Stirling Water-Tube Boilers
Type H Stirling Water-Tube Boilers
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Bailey Water-Cooled Furnaces

Superheaters
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Economizers
Air Heaters

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Chain-Grate Stokers
Oil Burners
Gas Burners
Multifuel Burners

Stacks and Breechings

Seamless Steel Tubes and Pipe
Seamless Alloy Tubes and Pipe
Seamless Toncan Iron Tubes
Alloy Pipe Fittings

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- B & W 80 Firebrick
- B & W Junior Firebrick
- B & W Insulating Firebrick
- B & W Refractory Mortars and Plastics
- B & W Laboratory Furnaces

Penstocks

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- Heat Exchangers
- Tubular Products
- Alloy Castings

Mercury-Vapor
Heat-Transfer Equipment

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Sulphite Cooking System

Pulverizers for Cement Materials,
Rock Products, and Ores

Elverite Castings
Adamantine Castings

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CLEVELAND......Guardian Building	NEW YORK.........85 Liberty Street	TULSA, OKLA....Thompson Building
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THE BABCOCK & WILCOX COMPANY

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